

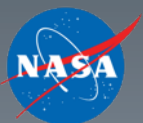
Ames Stereo Pipeline

Terry Fong

Director, Intelligent Robotics Group
NASA Ames Research Center

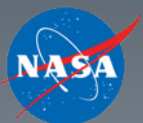
terry.fong@nasa.gov

April 9, 2013

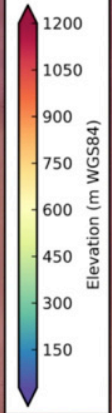


Ames Stereo Pipeline

- Automatic **Stereo Correlation** (*matching all pixels between two images*) for large satellite images.
- Camera models for NASA planetary rovers, NASA planetary satellites, **DigitalGlobe Satellites**, and generic RPC Models.
- Multithreaded and can be used across multiple machines. Works on high-end workstations to super computers.



WorldView DEM Mosaic (7/9/10-7/11/10)



3-5 m/px
2500 sq. km
6 input images

Z195

Z216

M6

M9

Z387

M13

Z603

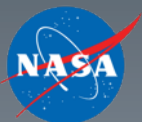
M17

M20



Example DEM Mosaic of Jakobshavn Glacier produced
by D. Shean U of W using Ames Stereo Pipeline

0 4 km



Legend

ESP_011672_1395-DEM_CMAP

ESP_011672_1395-DEM

-5900.0

-5680.0

-5460.0

-5240.0

-5130.0

-4910.0

-4800.0

ESP_011672_1395-DEM_MOLA_HILL

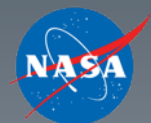
0-255

2 m/px
45 sq. km
2 input images

0.5 0 0.5 1 1.5 km

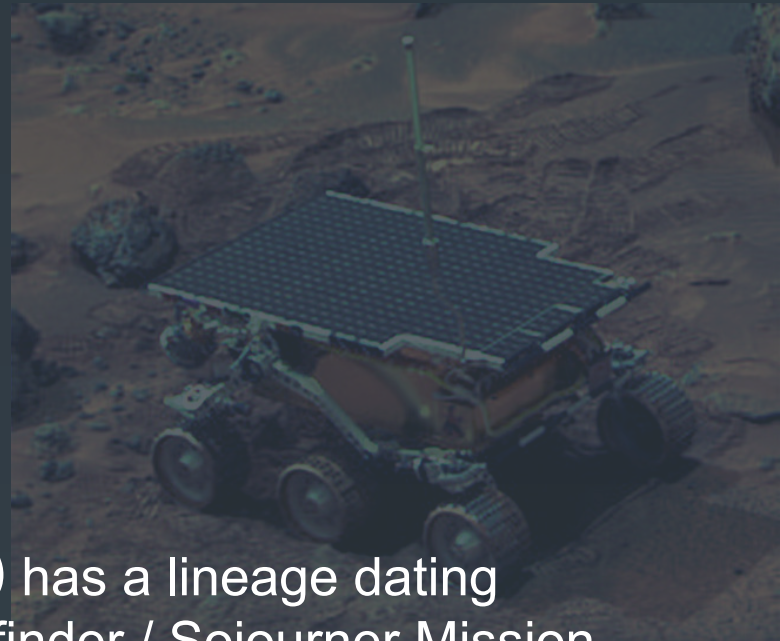


Example DEM of an unnamed crater created from Mars Reconnaissance Orbiter imagery using Ames Stereo Pipeline.



History

- Ames Stereo Pipeline (*ASP*) has a lineage dating back to the 1997 Mars Pathfinder / Sojourner Mission.
- October 2009 ASP v1 rewritten for satellite support and open-source released (*NASA Open Source*)
- June 2012 ASP v2 includes support for DigitalGlobe and open-source released (*Apache 2 license*)



How it works

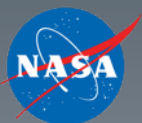
- Ames Stereo Pipeline is a set of command line tools.
- Designed for computing clusters and super computers.
- UNIX derived platforms (Linux, Mac OSX, etc)

```
~PRJDIR/StereoPipeline/data/CTX(branch:master*) » stereo *cal.cub run/run -s stereo.nonmap
Warning! Your current config file enables debug logging. This will be slow.
--> Detected ISIS cube files. Executing ISIS stereo pipeline.

Creating output directory: "run"
Using "stereo.nonmap"

[ 2013-Apr-01 14:53:58 ] : Stage 0 --> PREPROCESSING
--> Computing statistics for the left image
left: [ lo:0.0566257 hi:0.138582 m: 0.0925434 s: 0.0137999]
--> Computing statistics for the right image
right: [ lo:0.0616242 hi:0.143717 m: 0.099642 s: 0.0132815]
Processing Left
Processing Right
Building Descriptors
Found interest points:
left: 7500
right: 6103
--> Matching interest points
Forward:[*****] Complete!
Backward:[*****] Complete!
Matched 266 points.
Inlier cluster:
Triangulation Err: 12.222 +/- 3.7716 meters
Altitude : -1723.63 +/- 72.7998 meters
Reduced matches to 255
--> Aligning right image to left using homography:
Matrix3x3((1.23303,0.00688278,-677.459)(-0.00832956,0.99707,1341.66)(-5.24688e-07,-
2.74192e-08,1))
--> Normalizing globally to: [0.0566257 0.143717]
--> Writing normalized image: run/run-L.tif
left: [*****] Complete!
--> Writing normalized image: run/run-R.tif
right: [*****] 39%
[~/projects/StereoPipeline/data/CTX] :stereo *cal.cub run/run -s stereo.nonmap
Mon Apr 01 14:55 0! ..ImportantPair 1- ..sionWorkbench 2 stereo
```

Typical output on the terminal when using Ames Stereo Pipeline.

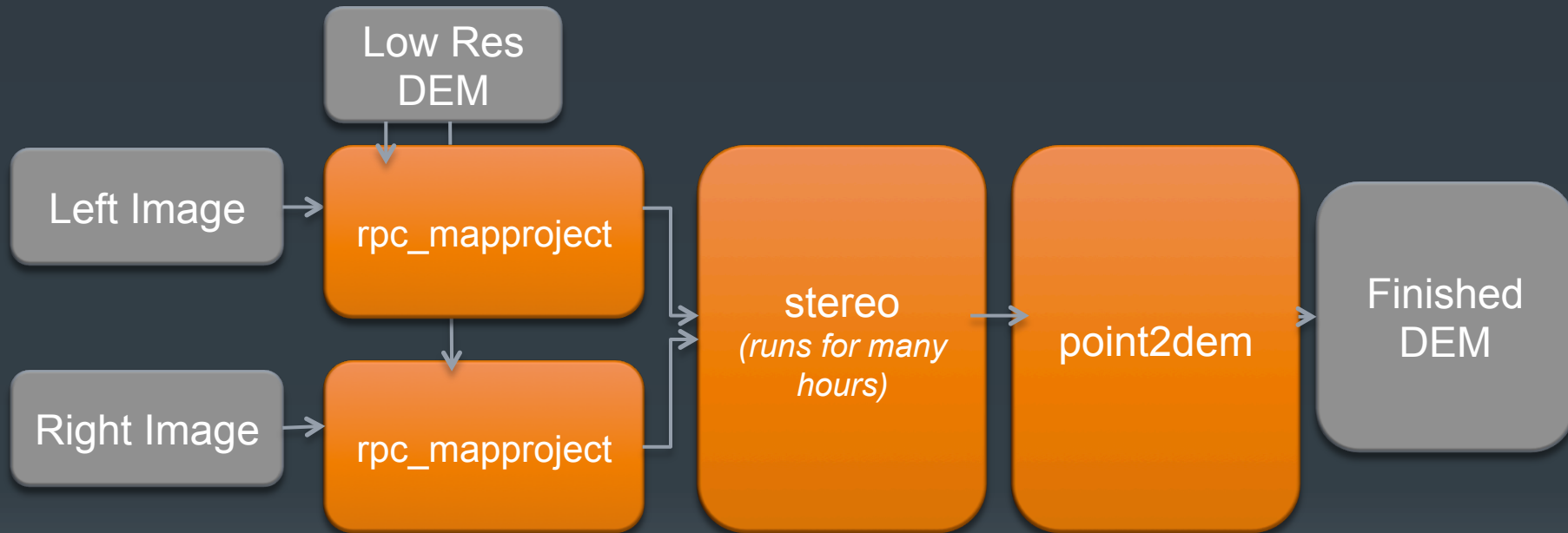


Typical User Operation



- In the simplest operation, the user only runs two commands from ASP.
- The **stereo** command creates a point cloud.
- The **point2dem** command converts the point cloud to DEM of your chosen projection.

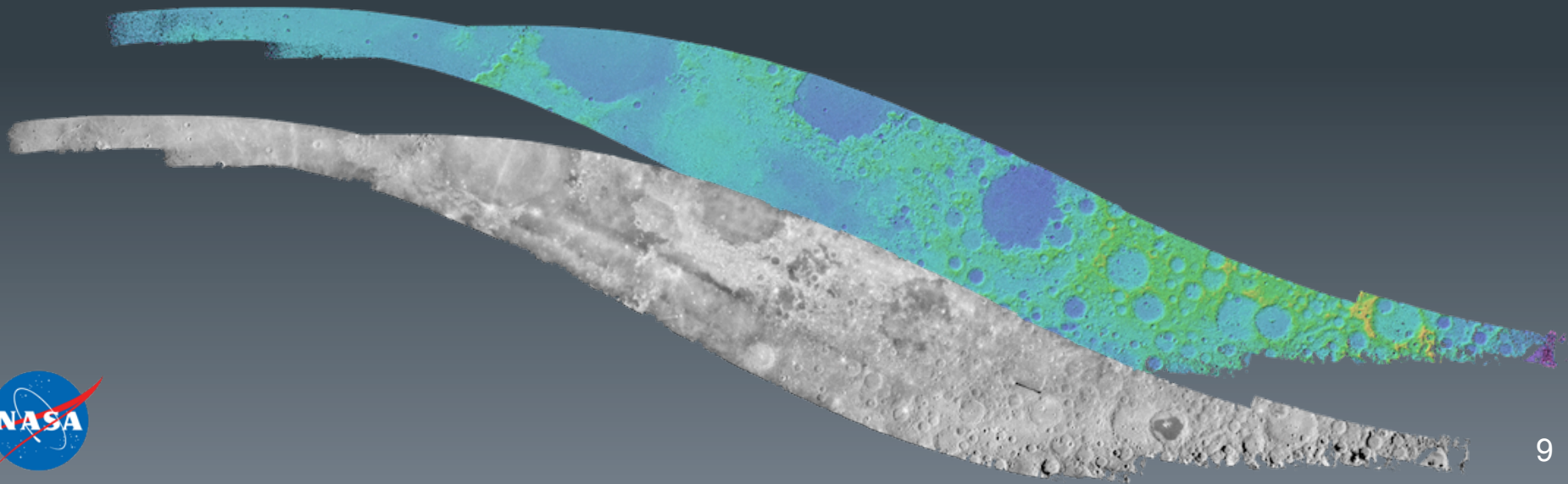
Advanced Operation



- Ames Stereo Pipeline can use existing DEMs to speed up its work.
- This operation is achieved by “map projecting” the input images prior to stereo correlation.

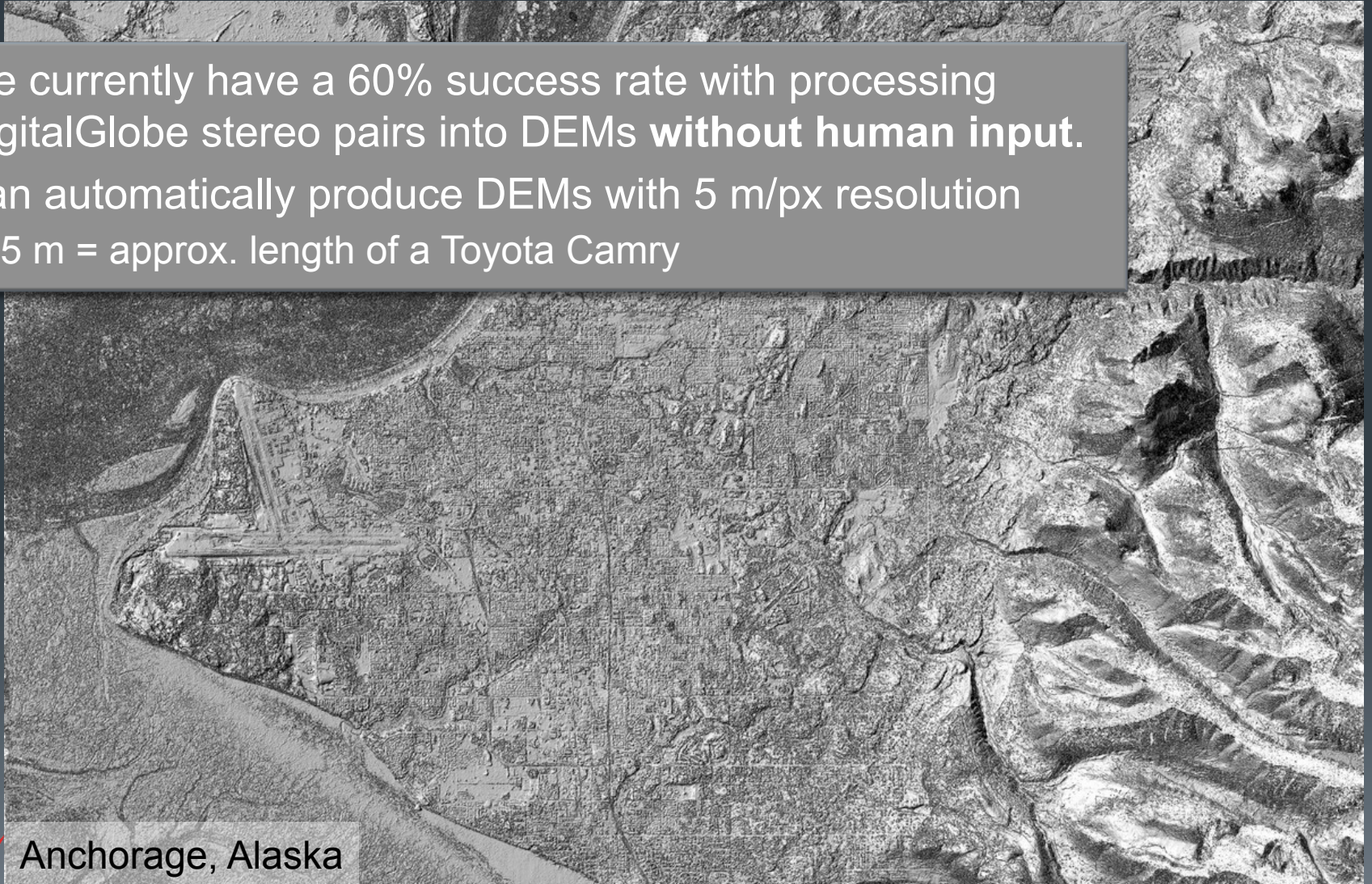
Our Past Applications

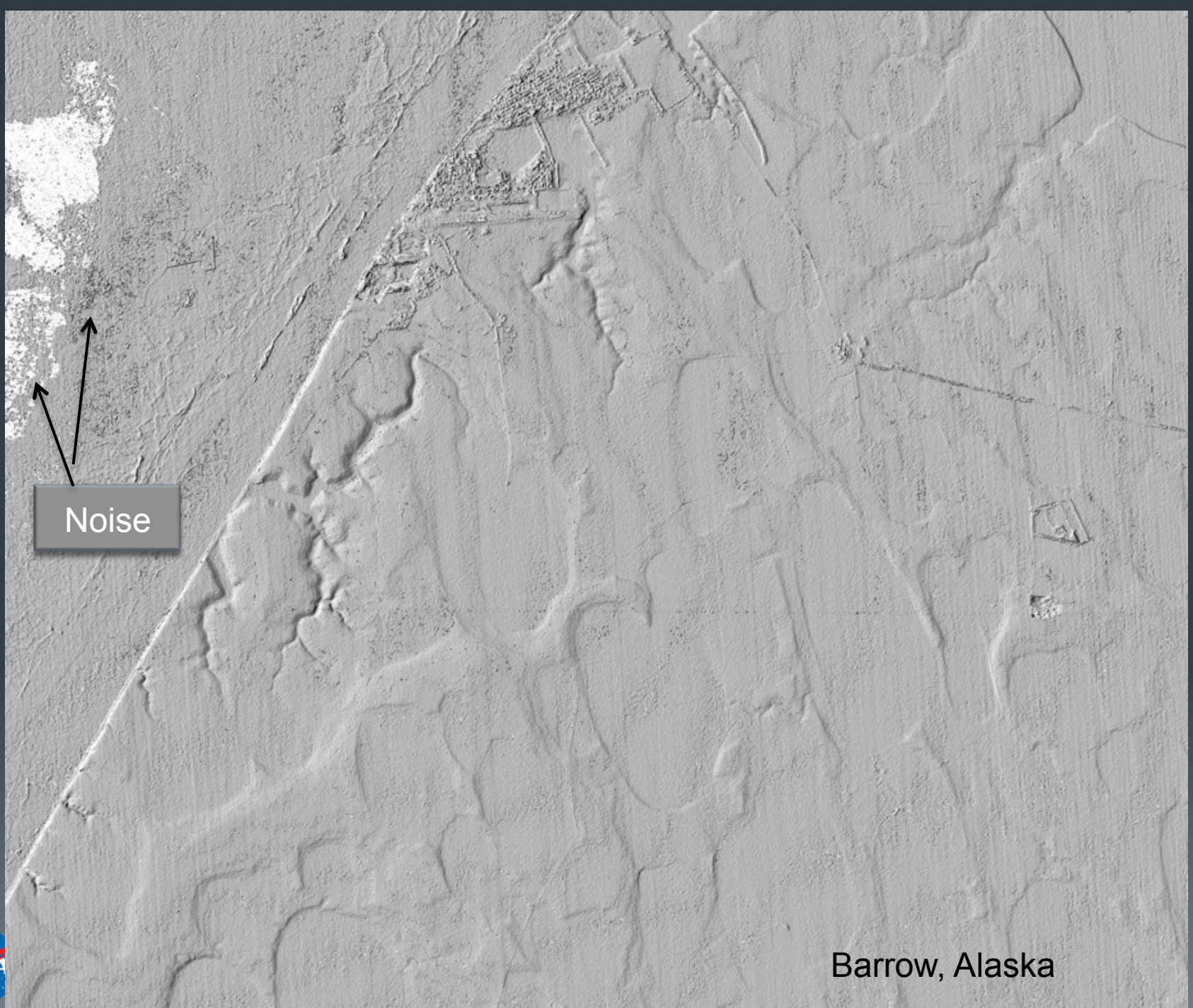
- We've used ASP to create 40 m/px DEMs from 3000 stereo pairs of the Moon (captured by Apollo 15, 16, and 17).
 - 40 m = approx. the length of 3 school buses end-to-end
 - The final mosaic covered 20% of the Moon
- These were all processed in a single week using the NASA Ames Pleiades Supercomputer



Autonomous Processing Earth Imagery

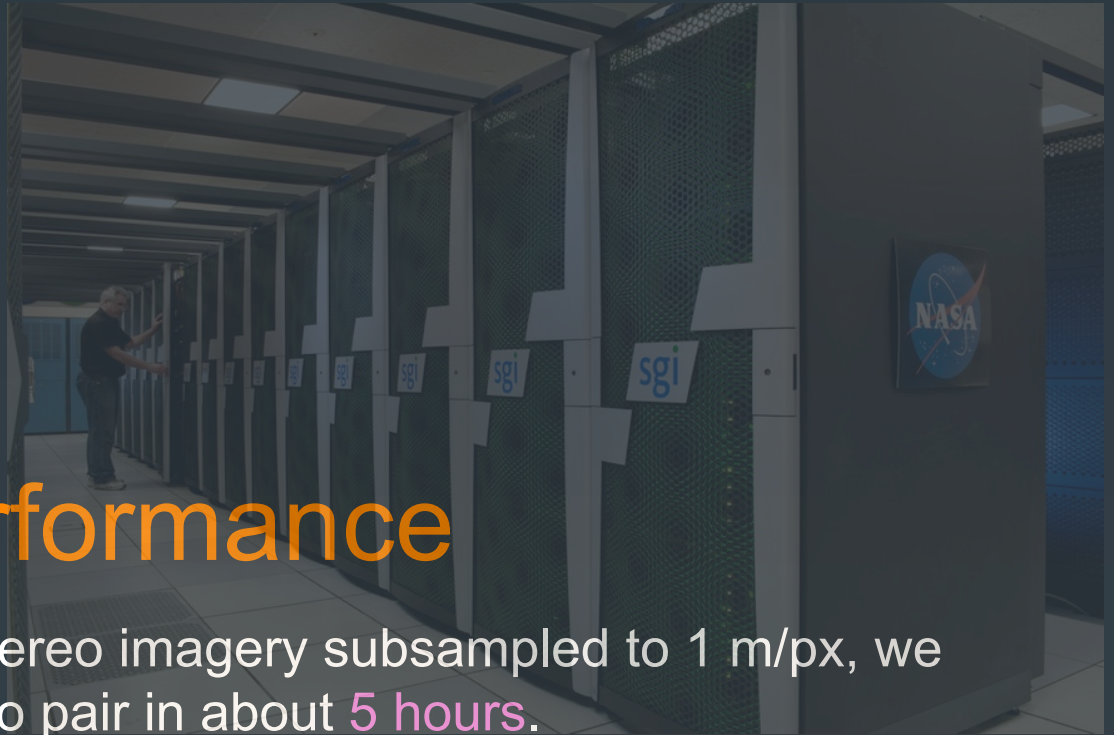
- We currently have a 60% success rate with processing DigitalGlobe stereo pairs into DEMs **without human input.**
- Can automatically produce DEMs with 5 m/px resolution
 - 5 m = approx. length of a Toyota Camry





Noise

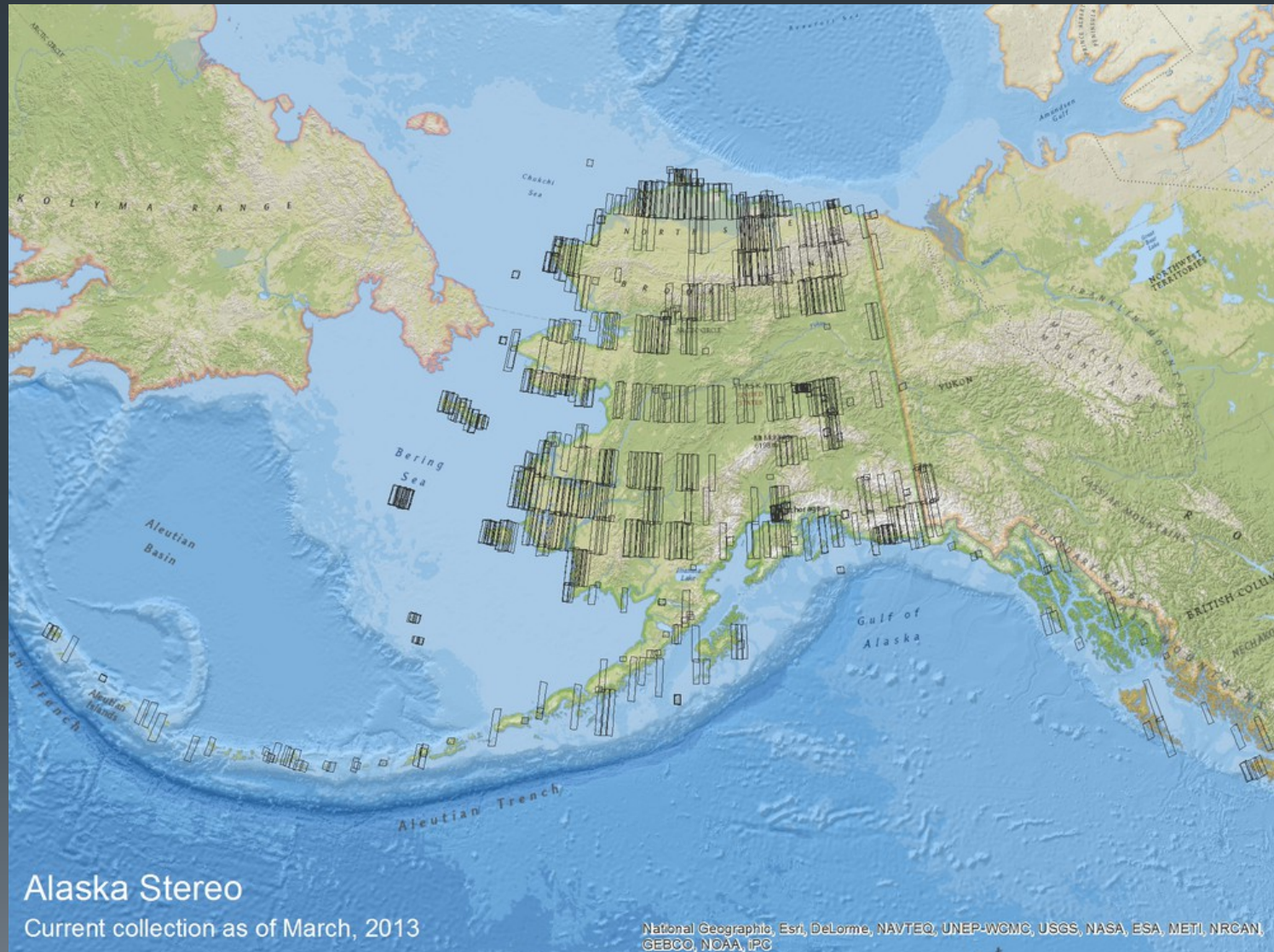
Barrow, Alaska



Typical Performance

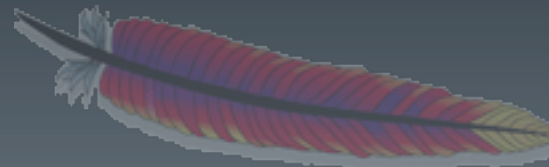
- With DigitalGlobe stereo imagery subsampled to 1 m/px, we can process a stereo pair in about 5 hours.
- Performance changes with the amount of parallax in the imagery.
- Processing cost is 5 minutes of CPU time / square km.
(on NASA Pleiades supercomputer, 3 GHz Xeon processors)

Stereo is Available



Software License

- Ames Stereo Pipeline v2 is available as open-source
 - Worldwide release (no country restrictions)
 - Can be freely reproduced and distributed, with or without modifications
- Apache 2 license
 - <http://www.apache.org/licenses/LICENSE-2.0.html>

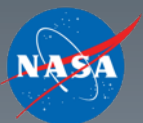




Source Code

- Our C++ code repository is hosted on Github.
- Ames Stereo Pipeline is part of the NASA “Neo Geography Toolkit”
- Available to download, copy, modify, collaborate, ...

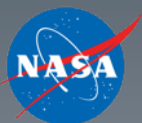
github.com/NeoGeographyToolkit/StereoPipeline



Prebuilt Binaries

irg.arc.nasa.gov/ngt/stereo

- Most Linux Distributions
 - 32 and 64-bit versions, RHEL 5+, SuSE, Debian
- Mac OSX 10.6+
- We do not support Windows



Additional images & technical

Lunokhod.org

- For more information:
 - Zack Moratto, Ames Stereo Pipeline PI
 - z.m.moratto@nasa.gov

